PRELIMINARY REPORT

ON THE

PROPOSED WATER-SUPPLY PROJECT

OF THE

CITY AND SUBURBS OF KOTAH

IN THE

RAJPUTANA AGENCY, INDIA,

TOGETHER WITH

AN ESTIMATE OF THE PROBABLE COST

PREPARED BY

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COMPLIMENTARY

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analysed by the Chemical Examiner to the North-Western Provinces, and all the samples, except those of two wells, one in the Agency and one in the Jail, were pronounced quite unfit for potable purposes.

2. *The Rampura Project.*—In July, 1890, the late Mr. Miles, then State Engineer, started a survey of a gravity scheme, the proposal being to enlarge and re-build a tank near the village of Rampura (*vide* Plan No. I) about 12 miles south of the city. The drainage area was 13 square miles which could, by diverting nullahs, be increased by 10 square miles more.

3. In a letter, dated 1st February, 1891, the Secretary to the Agent, Governor-General, for Rajputana, reported that he considered the gravity scheme should be abandoned, on the grounds that the supply of water available might in years of drought fall short of requirements, and he considered a pumping scheme from the River Chumbal, though more costly, to be preferable.

4. From 1891 to the end of 1894, analyses of water obtained from the existing Rampura Tank, and from various wells in and near Kotah, were made by the Chemical Examiner to the North-Western Provinces, but with the exception referred to above, none of the samples were well reported on.

5. *The Alnia Project.*—In 1895 Mr. Miles' report on an alternative scheme, the bunding up of the River Alnia was forwarded to the Agent to the Governor-General.

This project was a great improvement on the Rampura scheme. The river was to have been bunded up at a point about 13 miles south of Kotah by a masonry and earthen bund 2,600 feet long to form a tank 2½ square miles in area having a catchment of 70 square miles.

The estimated cost was Rs.6,37,500. In a note on the Kotah water-supply, dated 16th September, 1895, Mr. A. J. Hughes, C.I.E., then Secretary to the Agent, Governor-General, condemned the Alnia scheme. Appendix (A) attached to the present Report is a *verbatim* copy of Mr. Hughes' note.

6. *The present Project.*—Early in January, 1896, Mr. Hughes spent about 10 days in Kotah. He visited the proposed site of the Alnia Bund and finally disapproved of the project. He also inspected the city and the Chumbal River up to the Kerer Rapids, and under his guidance the following plans of the present project were prepared :—

(1) Theoretical discharge diagram of the C. I. Mains.

(2) Pipe-distribution for the city.

(3) Plans of Filters and Service Reservoir.

7. The present project provides for the supplying of 40,000 persons with an allowance of 15 gallons per head, *i.e.*, for 600,000 gallons daily.

8. The Kotah Pool of the Chumbal River, extending as it does for 2 miles below and $8\frac{1}{2}$ miles above the city, and averaging 500 feet in width and from 10 feet to 25 feet in depth, forms an inexhaustable supply of water.

9. At the city itself the water is far purer than many of the wells; 3 miles above the city samples of the river water have been found by the Chemical Analyser to the North-Western Provinces to be almost pure, and 8 miles above to be absolutely so.

10. This extensive pool in the river after the rains, *i.e.*, during September, is at a level of about 744 above M. S. L., and it does not subside more than 8 feet during the following nine months.

11. In the rains the river is liable to very high floods indeed. On the 16th August, 1896, it rose to R. L. 778·2, *i.e.*, to 42 feet above its hot-weather level. The maximum flood-level is recorded by local tradition to be about R. L. 798 or 62 feet above its low-water level.

12. Mr. Hughes decided that, if sufficient water-power was not available for pumping purposes, the pumping-engine should be placed against the right bank of the Chumbal near the site of Gauge " B " (*vide* Index Plan No. I).

Eight and a half miles above Kotah are the Kerer Rapids which extend for 3,500 feet in a series of small rapids with total fall of 24 feet; another considerable pool occurs beyond these rapids, it has been called " Pool No. 2," and it extends for 6,500 feet. Above Pool No. 2 are the second rapids, 1,700 feet long, with a fall of $6\frac{1}{2}$ feet, and so on, a succession of pools and rapids as shewn in the Longitudinal Section of the River (Plan No. III).

On inspecting these rapids, Mr. Hughes admitted that there was sufficient water-power available to work a turbine for some months at all events during the year, but he left me to decide if it was possible only to supplement the steam-pumps, when water-power for a turbine was available, or whether the steam-pumps could be entirely dispensed with.

13. The question could only be decided by taking a series of observation of flood discharges and record of flood-levels for at least a year, and so far the last year observations have been taken.

The Gauge Book, Appendix " B," gives records of flood-levels of the River Chumbal at four different places marked A., B., C. and D., in Plans Nos. I and II.

The Gauge it is on the fort walls of the city near Kunari Ghat. The R. L. of its zero is 734·2. Gauge " B " is $5\frac{1}{2}$ miles up-stream in the Kotah Pool, and the R. L. of its zero is 734·1.

Gauge " C " is about 200 feet above the top of this pool in Rapid No. 1. The R. L. of this zero is 743·8; this is also the R. L. of the top of a small masonry wall which was built in February, 1896, across the river at this place. By means of the wall the low discharges of March, April, and May, 1896, were recorded.

Gauge " D " is 3,500 feet above the top of the Kotah Pool and at the head of Rapid No. 1.

14. All the water-power available has been recorded at Gauge " C, " which was the only convenient site for a discharge wall. It should be mentioned that the discharge wall was carried away in the floods of 1896, and so the gauge-readings at " C " after the rains do not bear comparison with those before the rains, but actual discharge observations were taken twice a month from November, 1896, and these will be kept up till a new gauge wall is built. A reference to the Gauge Book, Appendix " B," shews that from the daily readings of the level of the river, the theoretical discharges have been worked out, and the theoretical discharges have also been checked by actual discharge observations. The gauges prove that in ordinary years, from September when the heavy floods subside up till the first week in March of the following year, there is a discharge of never less than about 300 feet per second. This discharge falls to about 8 cubic feet per second at the end of March and remains at about this amount till the end of April ; it decreases to 4 cubic feet up till the 15th May, after which, till the beginning of the rains, the discharge may be assumed to be *nil.* During the rains the discharge gradually increases, and the usual violent fluctuations of Indian rivers occur till the end of August, after which the floods rapidly subside during September, and very gradually subside till the end of the following March.

15. These gauge-readings prove that turbines would work for at least seven months in the year and, by careful attention to levels and designing, they may be made to work for about two months more. If, therefore, during nine months they could pump up enough water for the whole year, and if at least three months' supply could be stored at a high level, steam-pumping could be dispensed with. This, in fact, is the design of the present project and the following description shews how it is proposed to be done.

16. The water-works project consists of the following works :—

I. *River Bed Channels* (*vide* Plan No. III).—These channels are numbered 1, 2 and 3, and are respectively 750, 2,000, 1,900 feet long.

They will be cut in the river-bed and will increase the length of Pool No. 2 from 6,500 to 15,500 feet, and its capacity (when bunded up as projected) between the levels 769 and 765 by about 28 millions cubic feet. This 28 millions cubic feet will form a useful reserve of water-power to work the turbines referred to further on in the Report.

II. *Masonry Bund in the Chumbal Bed.*—This will be made above the Kerer Rapids as shewn in Plans Nos. II., III., V., VI.

It will hold up water to a level of 769 above M. S. L. The foundations of this bund will have to be about 15 feet deep, and its maximum height in the deepest part of the river-bed

will be about 12 feet. On the right side of the bund there will be an outlet into an aqueduct, and the centre of the bund will form a waste weir by which all flood discharges, exceeding 157 cubic feet per second, will be passed off. Stop-valves placed at low-levels will be capable of emptying Pool No. 2 down to R. L. 759.

III. *Aqueduct from Bund to Turbine Wells* (*vide* Plan No. V.).—This will be made of stone masonry with a bed width of 8 feet and with side slopes ½ to 1 and with a fall of 2 feet in its total length of 2,500 feet. Its discharging capacity will be 157 cubic feet per second. At its head in the bund it will have a regulator so as to keep the discharge of the aqueduct up to the quantity required for pumping purposes. It will follow the right bank of the river and its depth will be 4 feet. The R. L. of its bed when it takes out at the bund will be 765, and the R. L. of its bed when it discharges into the inlet pipe of the turbines will be 763. At the tail of this aqueduct will be a second regulator to keep the discharges up to the requirements of the turbines.

IV. *Turbine and Pump Well.*—The design for this has been made out for the sake of the estimate, but it will have to be modified to suit the foundation plan submitted by the contractors who supply the machinery. The wells and tower will be of oval form built against the right bank of the Chumbal just below the Kerer Rapids (*vide* Plans Nos. V. and VII.).

V *Turbines, Pumps and Rising Main.*—There will be two turbines and two Worthington pumps. The R. L. of the inlet pipe of the turbines from the aqueduct will be 763. One turbine will be placed at R. L. 743 and the other at R. L. 748. The former will thus have a working fall of 20 feet and will require a discharge of 65 feet per second, and the latter will have a working fall of 15 feet and will require a discharge of 86 feet per second (*vide* calculations accompanying, Appendix "C"). Each turbine will be accompanied by a Worthington pump, but it must be possible to gear either turbine on either pump. Each pump will be accompanied by a rising main, which will pump into the high-level tank placed at R. L. 1,028 in the right bank of the Chumbal.

Each turbine and pump will be capable of lifting 50,000 gallons of water per hour (*i.e.*, 600,000 gallons a day of 12 hours) 292 feet (vertical lift) above the low-water level of the river by each rising main: 600,000 gallons a day is the full requirements of the Kotah city and suburbs, so that both turbines working 24 hours a day can pump up four times the actual requirements.

The rising mains will each be about $\frac{1}{4}$ of a mile in length with a vertical rise of 292 feet. They may be 9 inches to 12 inches in diameter.

The Contracting Engineer, who supplies the pumps, will supply also the turbines and the rest of the pipes and fittings required for the pumping-works, and he will be required to send an Agent to superintend the fixing up of all of the machinery.

The specification for the machinery will be that one set of turbine and pumps should, by actual trial with power water of 65 cubic feet per second falling 20 feet into the turbine, be capable of pumping up 600,000 gallons of water in 12 hours or less by a rising main $\frac{1}{4}$ mile long and with a vertical rise of 292 feet to the high-level tank on the right bank of the Chumbal; also that the second turbine can by power water of 86 cubic feet per second falling 15 feet be capable of similar work.

The Contractor may make his own choice of type of turbines to be used, diameters of inlet pipe, turbine wheel, &c., but the pump should be of the Worthington type. He may make his own calculation of the loss of head by friction in the rising main. The turbines and pumps will have to be kept in working order by the Contractor for six months commencing from the 1st of September, the cost of working the machinery being borne by the State, the Contractor paying only the Agent's salary.

From calculations accompanying this Report it will be seen that 65 and 86 cubic feet per second of water falling 20 feet and 15 feet respectively will develope sufficient power to work both sets of pumps, and each set of pumps will be capable of delivering 600,000 gallons of water in 12 hours into the high-level tank on the top of the Chumbal. From the high-level tank water will be carried by a masonry duct to the collecting tank (*vide* Plan No. II), where four months' supply of water can be stored. The water from the collecting tank will be carried by a C.-I. main to the filter-beds, of which there are three (two always to be in use). From the filter-beds the water will gravitate to the Service Reservoirs, which will be roofed in to contain each one day's supply, and from the Service Reservoirs the water will be carried by a 15 C.-I. main and distributed, as shewn in Plan No. XIII., to the city and to the out-lying villages of Sakatpur, Kunari, Chaoni, and to the New Palace and other houses lying to the extreme north of the city.

VI. *High-level Tank and Masonry Duct to the Collecting Tank.*—The high-level tank will be of plain masonry $50' \times 50' \times 6'$ in depth.

The rising main will deliver into it at a height of 5 feet above the bed and a masonry duct with a discharging capacity of 10 cubic feet per second will carry off the water forced up by both pumps working together. The masonry duct will be connected direct with the filter-beds as well as with the collecting-tank, so that water can be delivered direct to the city or to the collecting-tank as may be necessary.

VII. *The Collecting Tank.*—This is formed in a natural depression in the ground by a bund 1,200 feet long and varying from 0 to 28 feet above the ground surface.

The principal levels are :—

Top of bund	=1,020
Top of waste weir	=1,015
Centre of outlet pipe	= 998
Lowest level of tank and of scour pipe ...	= 993

The outlet is designed so as always to take water at the surface of the lake. The capacities of the tank at different levels are shewn on Plan No. X. The total capacity is about four months' supply for the whole city.

VIII. *C.-I. Main to Filter-beds.*—This is laid with a slope of 5 in 1,000, so to supply 833 gallons per minute its diameter will have to be 11 inches.

IX. *Filter-beds.*—There are three of these, each $100' \times 75' \times 7\frac{1}{4}'$. Two will be in use and the third will be spare.

X. *Service Reservoirs.*—There are two of these, each $100' \times 70' \times 15'$, *i.e.*, with a capacity of 632,000 gallons equivalent to slightly more than one day's supply.

XI. *C.-I. Main to City and Pipe-distribution.*—The C.-I. main to the city is 11,000 feet long, and for a discharge of 833 gallons per minute its diameter should be 15 inches.

The pipe-distribution is arranged as shewn in Plan No. XIII., and calculated as shewn in the theoretical discharge diagram (Plan No. XIV.).

The total length of C.-I. pipes are as follows :—

Rg. ft.	Inch.
11,000	15 pipes.
3,500	12 „
3,300	10 „
3,600	8 „
3,300	7 „
13,800	6 „
8,200	5 „
21,400	4 „
9,100	3 „
7,364	$2\frac{1}{2}$ „

Fire hydrants will be provided at about 500 feet intervals in the city, and ordinary hydrants as shewn in the plan. All State buildings will be connected by W.-I. pipes from the main pipes.

XII. *Miscellaneous Works.*—A sum is provided in the estimate for electric lighting of the pumping-station, which will be done by a small dynamo and accumulator worked by the turbines.

Workmen's Quarters at the Pumping-station.—These will have to be built on the right bank of the river, as near as possible to the Pumping-station (*vide* Plan VIII.).

Steps down to the Pumping-station.—These will have to be built to accompany the rising main if possible. A small Inspection-bungalow and Overseers' quarters near the Pumping-station will also be required to be made.

17. The above works represent the whole scheme of the Kotah Water-Works as now projected.

18. To understand how they will work, it is necessary to refer to the Gauge Book of the River Chumbal, which accompanies the Report (Appendix B).

Gauges were recorded from March 7th to May 16th at "C" and also from July 25th up to date.

Gauges A., B. and D. were recorded only from July 25th up to date.

19. The R. L. of the low-level turbine is at 753, and water in the Kotah Pool may rise up to this level and the turbines would still work.

The R. L. of the zero of Gauge A= 734·2 and of Gauge B = 734·1. Referring to the Gauge Book on dates when the flow in the river was steady, *i e.*, in November and December, we find the fall in the water-surface from Gauge B to Gauge A = 0·6.

The distance from Gauge A to Gauge B is 5½ miles, and from Gauge B to the turbine site is 2½ miles. By proportion therefore the surface of the Kotah Pool at the turbine escape is then 1·3 foot higher than at Kunari Ghat or Gauge A. From this it is evident that the low-level turbine will be in working order, so long as Gauge A does not read higher than R. L. 743 – 1·3=741·7. By similar reasoning the high-level turbine being at R. L. 748 it will work so long as Gauge A does not read higher than 748 – 1·3=746 7.

20. Referring to the Gauge Book we find that the low-level turbine will cease working on or about July 29th, and remain drowned till about September 5th, *i.e.*, for one month and 15 days. About the 9th of September this turbine can recommence working, and there will always be enough water in the river to work it until about the 13th of March, *i.e.*, for

about six months and four days. From the 13th to the 21st the low-level turbine only will be working day and night. From the 21st to the 31st of March this turbine can work only 12 hours a day.

During April the discharge of the river may be assumed to be 8 cubic feet per second, and the low-level turbine requires for 12 hours' work 2·8 million cubic feet. The total discharge of the river during April will be

$\overset{\text{days.}}{30} \times \overset{\text{sec. per day.}}{86{,}400} \times 8 = 20{\cdot}7$ million cubic feet.

There is stored in Pool No. 2 [*vide* para. 14 (I)] 28 million cubic feet. Total water-power available in April $= 20{\cdot}7 + 28 = 48{\cdot}7$ million cubic feet, and as one turbine wants 2·8 million cubic feet per day, it is obvious that one turbine will work $17\frac{1}{2}$ days of 12 hours. During May and June the discharge of the river may be taken at 4 cubic feet per second for 15 days.

That is, at $15 \times 86{,}400 \times 4 = 5{,}184{,}000$, so that in this period the low-level turbine will work two days of 12 hours.

The rains may be taken to commence on the 1st July and up till the 29th, both turbines will be in full working order, both day and night.

21. The high-level turbine will be less efficient in the months of April and May and part of June, but during the rains it will work for a considerably longer period.

The following table shews how both turbines will work during the year:—

MONTH.		LOW-LEVEL TURBINE.		HIGH-LEVEL TURBINE.		EITHER H.-L. TURBINE OR LOW-LEVEL TURBINE.	
Name of—	Number of days.	Number of working days of 24 hours each.	Number of working days of 12 hours each.	Number of working days of 24 hours each.	Number of working days of 12 hours each.	Number of working days of 24 hours.	Number of working days of 12 hours.
January ..	31	31	..	31	..	31	..
February ..	28	28	..	28	..	28	..
March ..	31	21	10	13	..	21	10
April ..	30	..	17	..	..	..	17
May ..	31	..	2	..	..	..	2
June ..	30	..	..	..	..	..	..
July ..	31	29	..	30	..	30	..
August ..	31	1	..	15	..	15	..
September ..	30	25	..	30	..	30	..
October ..	31	31	..	31	..	31	..
November ..	30	30	..	30	..	30	..
December ..	31	31	..	31	..	31	..
TOTAL ..	..	227	29	239	..	247	29

Thus during the year the low-level turbine can work 24 hours a day for eight months and the high-level turbine for almost exactly the same period; but as the high-level turbine will be in working order at some periods of the year when the low-level turbine is drowned and incapable of work, at least one turbine will be in working order for a period of eight months and 21 days (taking a day at 24 hours); or if a day of 12 working hours is taken, at least one turbine will work for nine months and seven days in the year, or say nine months. In nine months one turbine working 12 hours a day will pump up $1\frac{1}{3}$ year's supply of water, so the probable period of working of one turbine will be about eight hours a day, and when both turbines work together, the surplus water pumped up will be stored in the collecting reservoir. As the collecting-tank can store at least three months' supply, there will always be enough water available during the inactive periods of the turbines.

22. *The present Project as compared with the Steam-Pumping Project.*—The total cost of the present project including 10 per cent. for establishment and contingencies amounts to Rs.7,09,153. If the pumping had been done by steam-power the estimate, as compared with the present estimate, would have been as follows :—

	Water power.	Steam-power.
	Rs.	Rs.
I.—River-bed channels	7,566	..
II.—Masonry bund	56,984	..
III.—Aqueduct	33,328	..
IV.—Pump, well or tower	29,989	29 989
V.—Pumping-machinery and rising main	71,990	71,990
VI.—High-level tank masonry duct	28,889	1,684
VII.—Collecting-tank	40,000	..
VIII.—C.-I. Main to Filter-beds	58,471	..
VIII (*a*).—C.-I. Main to settling-tanks	..	46,777
VIII (*b*).—Settling-tank	..	24,000
IX.—Filter-beds	33,493	33,493
X.—Service Reservoir	35,641	35,641
XI.—C.-I. Main to City and Pipe-distribution ..	2,30,174	2,30,174
XII.—Miscellaneous	18,160	18,160
Contingencies	64,468	49,190
TOTAL ..	7,09,153	5,41,098

Thus the present water-power pumping scheme as compared with a steam-power scheme seems to cost Rs.1,68,055 more, but when the respective maintenance charges are taken into consideration the water-power project shews itself to be much the better project.

The cost of maintenance will be about Rs 5,000 annually for each project, but the steam-pumping will cost in addition Rs.25,800 per annum for coal.

Thus assuming 40lbs. of coal are used to pump one million gallons of water 1 foot high we get the annual tonnage of coal required to be for 600,000 gallons of water a day pumped 220 feet high.

Coal required $= \frac{220 \times 600{,}000 \times 365 \times 40}{1{,}000{,}000}$ lbs $=$ 860 tons, which may be taken to cost Rs.25,800.

	Rs.
A fixed charge of Rs 25,800 per annum, at 4 per cent., represents a capital of Rs.6,45,000, and so, from a financial point of view, the cost of the Steam-Pumping Project should be taken to be actual cost	5,41,098
Funded amount required to work ditto	6,45,000
TOTAL ...	11,86,098

and so as compared to the Steam-Pumping Project the Water-Power Project may be said to be Rs.4,76,945, cheaper.

23. The only thing that remains to be considered is that possibly there are disadvantages or risks to be encountered in the Water-Power Project which do not exist in the Steam-Power Project.

The construction of a bund across the Chumbal will, no doubt, be a difficult matter, and as the river-bed at the Kerer Rapids is gravelly and full of very large boulders, the foundations will have to be carried down to the solid rock below, and the work will have to be done rapidly during the dry season of the year.

Though an expensive bund, owing to the depth of foundations required, if constructed as designed, it may reasonably be expected to remain water-tight and uninjured during floods. A bund of smaller section has been made across the Parbatti River in the Kotah State, but the Parbatti is not subject to such high floods at its bund site as the Chumbal. The aqueduct is another work which will, of course, run considerable risks of damage during floods, but when damaged it can be easily repaired again after the floods subside.

The collecting-tank containing four months' supply of water will of course be more leaky than a small settling-tank of one day's supply, which would be necessary for the Steam-Pumping Project, but there is no reason to doubt that it can be made sufficiently water-tight.

As regards the wells for the pumping-machinery, the turbines have the advantage over steam-engines, as they will bear complete immersion with water, and thus the strain on the well walls and the danger of the floor blowing up by water-pressure from without can be avoided.

In other respects the projects are all similar, and there can be but little doubt that the Water-Power Project is much the best of the two.

24. As regards funds, it should be stated that Rs.66,220 has already been sanctioned and mostly spent for pipes and small pumping-machinery for the water-supply to the New Palace. Of this Rs.58,810 represents the amount which can be deducted from the present project, the rest of the expenditure being for machinery, &c., which is of no use in this project.

A further allotment of Rs.50,000 has been made in the State Works Budget for 1896-97, all of which can, if the present project is approved, be spent in the present official year. If early approval and sanction to the project is received, the following proposals for allotment of funds is suggested :—

	Rs.
Thus funds allotted in 1895-96 and of which a portion only goes towards the present project	58,810
Funds already allotted for 1896-97	50,000
Further funds asked for in 1896-97, if early sanction to the project is received	50,000
Funds required for 1897-98	3,00,000
Ditto for 1898-99	2,50,343
TOTAL ...	7,09,153

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ESTIMATE OF COST.

KOTAH WATER-WORKS.

Abstract No. 1.—Probable Cost of River Bed Channels.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
	River Bed Channels.			
235,560 c. ft.	Excavation in River-bed of Rock and Boulders	3	100	7,066
	Masonry Regulator at tail end of Channel No. 1	..	..	500
	TOTAL Rs. ..	..	..	7,566

Abstract No. 2.—Probable Cost of a Masonry Bund in the Chumbal River.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
	Masonry Bund in Chumbal.			
465,355 c. ft.	Excavation of foundation	1	100	4,635
197,940 "	Concrete	9	"	17,814
95,514 "	Coursed rubble masonry	10	"	9,551
53,620 "	Superstructure masonry	12	"	6,434
9,990 "	Stone on edge paving	14	"	1,398
688,880 "	Sand or earth bund	6	1,000	4,132
30,000 "	Rock blasting	6	100	1,800
	Pumping operations	Lumpsum		5,000
3 No.	Stop-valves	600	each.	1,800
222 cwt.	Iron pipes	10	cwt.	2,220
4 No.	Outlet gates	300	each.	1,200
	Workmen's huts	Lumpsum		1,000
	TOTAL Rs. ..	..	..	56,984

KOTAH WATER-WORKS.

Abstract No. 3.—Probable Cost of a Masonry Aqueduct from the Chumbal to Turbine Wells.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
525,000 c. ft.	Excavation of foundation	5	1,000	2,625
133,750 "	Concrete	9	100	12,037
110,416 "	Coursed stone masonry	10	"	11,041
38,750 "	Stone on edge masonry	14	"	5,425
	Blasting or Removal of boulders ..	..	..	1,000
10,000 c. ft.	Stone masonry retaining walls ..	12	100	1,200
	TOTAL Rs. ..	..	..	33,328

Abstract No. 4.—Probable Cost of Turbine Wells.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
556,000 c. ft.	Excavation	7	1,000	3,892
97,000 "	Concrete	9	100	8,730
140,000 "	Stone masonry	12	"	16,800
4,050 "	Stone on edge masonry	14	"	567
	TOTAL Rs. ..	..	..	29,989

Abstract No. 5.—Probable Cost of Turbines, Pumps and Rising Main.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
2	Sets of turbines and pumps with inlet pipes of turbines, shafts and wheels for connection with pumps and all necessary fittings, including cost of carriage and erection ..	30,000	each.	60,000
1,090 cwt	Of 12-inch rising main including special pipes and all necessary valves and cost of carriage and erection	11	cwt.	11,990
	.. TOTAL Rs. ..	..	..	71,990

KOTAH WATER-WORKS.

Abstract No. 6.—Probable Cost of High-Level Tank and Water Duct.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
	High-Level Tank.	Rs.		Rs.
14,810 c. ft.	Excavation of foundation	1	100	148
3,510 „	Concrete	9	„	315
5,427 „	Stone masonry	12	„	651
140 „	Stone on edge masonry	14	„	19
4,784 s ft.	Pucca plaster	4	„	191
2 No.	Sluice-valves 12-inch	180	each.	360
				1,684
	Aqueduct.			
336,000 c. ft.	Excavation	5	1,000	1,680
58,500 „	Concrete	9	100	5,265
60,000 „	Stone masonry	12	„	7,200
79,000 „	Stone on edge masonry	14	„	11,060
				25,205
	Aqueduct over nullah	..	..	2,000
	TOTAL Rs. ..	..	..	28,889

Abstract No. 7.—Probable Cost of Collecting-Tank.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
	Collecting tank	..	..	40,000
	TOTAL Rs. ..	..	..	40,000

Abstract No. 8.—Probable Cost of C.-I. Pipes from Collecting-Tank to Filter-Beds.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
8,353 cwt.	Of 11-inch C.-I. Spigot and Socket-pipes..	7	cwt.	58,471
	TOTAL Rs. ..	..	..	58,471

KOTAH WATER-WORKS.

Abstract No. 9.—Probable Cost of Filter-Beds.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs. a. p.		Rs.
31,693 c. ft.	Excavation foundation	4 0 0	1,000	1,268
4,566 „	Concrete in walls	9 0 0	100	411
3,802 „	Ditto in floor	9 0 0	„	342
12,459 „	Stone masonry	12 0 0	„	1,495
1,288 „	Do. coping	40 0 0	„	515
7,199 s. ft.	Slab flooring	10 0 0	„	719
36,813 c. ft.	Filling earth for slopes	4 0 0	1,000	147
4,496 „	Brick kharanjah	8 0 0	100	359
4,903 „	Gravel	3 0 0	„	147
3,750 „	Coarse sand	3 0 0	„	113
19,142 „	Fine sand	4 0 0	„	766
10,932 s. ft.	Plaster	4 0 0	„	437
	Total for one Filter-bed, Rs. ..	..	..	6,719
	Cost of three Filter-beds	6,719 0 0	each.	20,157
	Iron-work.			
210 r. ft.	1 inch Wrought-iron pipes.. ..	0 3 0	ft.	39
1,248 cwt.	15 „ Pipes (to Service Reservoir) ..	7 0 0	cwt.	8,736
93 „	15 „ Special pipes	10 0 0	„	930
11 No.	15 „ Stop-valves	308 0 0	each.	3,388
17 cwt.	6 „ Pipes	7 0 0	cwt.	119
4 „	6 „ Special pipes	10 0 0	„	40
3 No.	6 „ Stop-valves	28 0 0	each.	84
		..	..	13,336
	TOTAL Rs. ..	..	..	33,493

KOTAH WATER-WORKS.

Abstract No. 10.—Probable Cost of Service Reservoir.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs. a. p.		Rs.
134,726 c. ft.	Excavation foundation	8 0 0	1,000	1,077
14,891 „	Concrete	9 0 0	100	1,340
10,070 „	Do. in floor	9 0 0	„	906
53,262 „	Stone masonry	12 0 0	„	6,391
3,524 „	Archwork	25 0 0	„	881
7,748 s. ft.	Slab roofing	36 0 0	„	2,789
415 „	Cut stone masonry	0 4 0	foot.	104
30 „	Do. of jali	3 0 0	„	90
77,958 c. ft.	Earthen slopes	2 0 0	1,000	156
34,150 s. ft.	Pucca plaster	4 0 0	100	1,366
7,696 c. ft.	Filling earth on roof	3 8 0	1,000	26
2 No.	Stone chowkuts of doors	8 0 0	each.	16
3 „	Ditto of window ..	5 0 0	„	15
92 s. ft.	Teak-framed doors	2 0 0	foot.	184
217 r. ft.	Girdana	0 2 0	„	27
383 s. ft.	Chujja	0 6 0	„	144
28 c. ft.	Stone coping drain	2 8 0	„	70
				15,582
	Cost of two Service Reservoirs ..	15,582 0 0	each.	31,164
	Iron-work.			
175 cwt.	C.-I. Pipes, Spigot and socket ..	7 0 0	cwt.	1,225
4 No.	Stop-valves, 15-inch	308 0 0	each.	1,232
42 cwt.	Special C.-I. pipes	12 0 0	cwt.	504
68 „	C.-I. Spigot and socket-pipes, 6-inch ..	7 8 0	„	510
5 „	C.-I. Special 6-inch pipes	10 0 0	„	50
2 No.	Stop-valves, 6-inch	78 0 0	each.	156
	Iron fittings, carriage and fixing of pipes..	Lump sum	..	800
				4,477
	TOTAL Rs. ..	..	..	35,641

KOTAH WATER-WORKS.

Abstract No. 11.—Probable Cost of Pipe-distribution.

Estimate No. 37 of 1896 97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs. a. p.		Rs.
28,794 cwt.	C.-I. Pipes, 15" to, 2½"	7 0 0	cwt.	2,01,558
	Stop-valves with flanged ends, each accompanied by one flange and spigot, and one flange and socket-end and surface-box.			
2	15-inch	308 0 0	each.	616
1	12 "	180 0 0	"	180
1	10 "	143 0 0	"	143
2	8 "	111 0 0	"	222
1	7 "	92 0 0	"	92
7	6 "	78 0 0	"	546
2	5 "	66 0 0	"	132
8	4 "	55 0 0	"	440
5	3 "	40 0 0	"	200
55	2½ "	33 0 0	"	1,815
579 cwt.	C.-I. Special pipes	10 0 0	cwt.	5,790
12	Street watering posts	95 0 0	each.	1,140
15	Pillar fountain and Hydrant stand-posts,	150 0 0	"	2,250
18	Hydrant stand-posts with two taps ..	33 0 0	"	594
25	Fire Hydrant and Surface boxes ..	60 0 0	"	1,500
25	Diaphragm, Hydrants and Surface-boxes,	32 0 0	"	800
	Wrought-iron Galvanized pipes ..	..	..	..
1,000	R. ft. of 2-inch	0 11 0	ft.	687
2,000	" 1½ "	0 9 0	"	1,125
3,000	" 1 "	0 5 0	"	937
2,000	" ¾ "	0 4 0	"	500
2,000	" ½ "	0 3 0	"	375
450	Quarter Bends, 2" to ½"	0 12 0	each.	337
250	Tees	0 12 0	"	187
188	Stop-valves, 2" to ½"	8 0 0	"	1,504
188	Bib-valves, 2" to 0"	8 0 0	"	1,504
	Masonry works	..	..	3,000
	Water-meters and Air-valves ..	..	..	2,000
	TOTAL Rs. ..	..	..	2,30,174

KOTAH WATER-WORKS.

Abstract No. 12.—Miscellaneous Works.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
	Electric Lighting at Pump Wells ..	..	..	5,000
	Workmen's Quarters	..	..	1,800
	Overseers' Temporary House and Office..	..	..	500
	Inspection Bungalow	..	..	2,500
	Steps down to Pump Site	..	..	8,360
	TOTAL Rs. ..	..	..	18,160

Abstract of Cost.

Estimate No. 37 of 1896-97.

Quantity.	Items.	Rate.	Per	Amount.
		Rs.		Rs.
I	Abstract—River-bed Channels ..	..	..	7,566
II	„ Chumbal Bund	..	..	56,984
III	„ Do. Aqueduct ..	..	..	33,328
IV	„ Turbine Wells	..	..	29,989
V	„ Turbines and Pumps ..	..	..	71,990
VI	„ High-Level Tank and Water Duct	..	..	28,899
VII	„ Collecting Tank	..	..	40,000
VIII	„ C.-I. Pipes to Filter-beds ..	..	..	58,471
IX	„ Filter-beds	..	..	33,493
X	„ Service Reservoir ..	..	..	35,641
XI	„ Pipe-distribution	..	..	2,30,174
XII	„ Miscellaneous works ..	..	..	18,160
				6,44,685
	Contingencies	10	100	64,468
	TOTAL Rs. ..	..	..	7,09,153

KOTAH WATER-WORKS REPORT.

APPENDIX A.

Copy of a Note on the Kotah Water-Supply, dated the 16th September, 1895, by A. J. HUGHES, ESQ., *C.I.E., M. Inst. C.E., Superintending Engineer, Rajputana and Central India.*

1. The population of Kotah, including the suburbs, is said to be 38,620. For Water-works purposes, the population may be taken at 40,000, and the required supply of water 600,000 gallons per day.

2. In the five years ending with 1893, the number of deaths ranged between 1,100 and 2,091. The average death-rate was 40 per thousand and the maximum 54 per thousand. It appears to be possible by good sanitary measures to effect a saving of 800 lives per annum, besides a proportionate share of preventible sickness.

3. The main feature in the surroundings of the town which produce this state of things is a tank above the city largely used for bathing and all purposes. Such tanks invariably serve as centres for the spread of all communicable disease, and they constitute one of the greatest difficulties in carrying out sanitary improvements in all towns owing to the tenacity with which they are adhered to by the population. Either this tank should be abolished or it should be neatly kept as an ornamental water, the sides being neatly trimmed and kept, and all bathing and washing in it prohibited.

4. The backwater in the drainage channel of this tank is also a sanitary difficulty mentioned in the papers. During the rains the river water backs up in this channel, which is progressively polluted during the time the water remains in it. I am not in a position to advise as to what should be done to avoid this difficulty until I have inspected the site.

5. The water-supply of the town is chiefly drawn from eleven wells, which draw their water from the percolation of the foul tank above referred to and from infiltration from the polluted city site. The analysis shews that the water in these wells is so very foul that little care can have been given to periodically and systematically cleaning them. To these insanitary conditions, recorded in the papers before me, must probably be added defective arrangements for the collection and safe disposal of rubbish, sweepings and privy contents. I hope to have the pleasure of conferring with the Political Agent and the Kotah authorities on the practical steps to be taken to remedy all the defects here outlined. The case on which my advice is now asked is with regard to the introduction of a pure water-supply, which the authorities rightly regard as the first great step in sanitary reform.

6. Two projects are under consideration—

1. A supply from the Chumbal which will involve pumping, settling and filtering the water, and a second set of pumps for delivering the water to the town.
2. The second project is for a storage reservoir.

If a suitable site for a storage reservoir can be found, it is undoubtedly the best and safest plan, but none of the sites now proposed are sufficiently good.

1. In the first place, a good reservoir dam must have a sound water-tight foundation. The experience for the district generally is that, owing to fissures in the sandstone rock, it is difficult to get such sites.

2. The second point in a good reservoir is that it must be able to provide for two years' supply to the town, *plus* an allowance of about 12 feet of depth for evaporation and percolation and *plus* about 15 feet of margin to allow for silting and other contingencies. A good reservoir should have a depth of about 20 to 25 feet above the sill of the water-tower, and a total depth of 35 to 40 feet. The depth of the reservoir now proposed is only 22 feet: it is the depth, and not the total capacity, of the water spread, which chiefly decides the fitness or otherwise of a site for a reservoir for a town-supply owing to the great loss from evaporation. With regard to the supply available, an inch of rain flowing off a square mile will produce 2,323,200 cubic feet, or from 70 square miles 163·1 millions of cubic feet. To meet two years' consumption a storage of about 200,000,000 cubic feet would be required and a reservoir a little less than a square mile in area should have a depth of 10 feet.

7. The water spread of the top 12 feet of the reservoir is immaterial, it will be lost in evaporation in two years. With fairly steep sides such a reservoir would lose 300 millions of cubic feet in two years from evaporation : so that in all, if a suitable site can be found, the required supply is about 500 millions of cubic feet equal to about 3 inches of flow off from the catchment of 70 square miles. If, as stated in the papers, the average rainfall is 29 inches for reservoir purposes, the rainfall of three consecutive bad years should be taken at 21 inches, and the flow off at about 3 inches. A good reservoir site, therefore, to answer practical purposes, and having a sound foundation would require to fulfil the following conditions :—

1. The top water spread should not exceed about 1½ square mile.
2. The depth of the reservoir should not be less than 35 feet at waste-weir level, and 40 feet will give better results.
3. The area of the catchment should not be less than 70 square miles.

The sites now proposed will not satisfy these conditions, and they must be rejected. Search should be made for a deeper reservoir with a smaller water spread (*a*) about the present site, or (*b*) along the proposed line of main for a storage reservoir. If a site can be found on (*b*) the site (*a*) may be used for raising the water to a suitable level, and the storage can be effected in (*b*) and a canal can be made to connect the sites.

The estimate for a storage project is likely to considerably exceed the six lacs entered in the present estimate.

8. The Chumbal project is a very safe one, and I think that it is likely to be the best.

The conditions are that the city is situated on a broad deep pool of clear water, about 14 miles long and (scaling from the map) about 500 or 600 feet wide. The water in this pool is headed up by a rocky barren across the channel about two miles below the town. The quality of the water is likely to be very good indeed up to February ; after February, up to the rains, the pool becomes still water and is liable to progressive contamination by the bathing and the washing of the population in the river and, perhaps, when the water-works are carried out, sewage of a very pronounced type may also find its way into the river if precautions are not taken to guard against this contingency.

If the river is used as a source of supply, therefore, an intercepting sewer or drain must be constructed to carry off the town sewage to a point on the river below the rocky barren above referred to. A 12-inch pipe laid at a suitable gradient will probably do all that is necessary in this direction. The sewage brought into the river by heavy rainfall may be disregarded. For safety the intake should be placed at about 3 to 5 miles above the town ; the estimate should be made for three miles, and the exact site for the intake should be determined by a series of biological examination of the water at

different distances from the city to ascertain how far the biological contamination of the river extends above the bathing ghats.

9. This investigation may be carried out by the local Medical Officer working under the instructions of Mr. Hankin, Chemical Examiner, North-Western Provinces, Agra, or samples of water may be sent to him for report.

The present analysis shews that pollution due to annual contamination extends certainly to three miles above the town, but that the degree of pollution is not greater than can be removed by effective settlement and filtration.

10. The question is not ripe for final decision as yet. A further examination must be made for suitable sites for a reservoir; but it is most probable that no good site for a reservoir can be found, and, in this case, the river with the assistance of good filtering arrangements will give a good supply. A very short examination of the country between the Alnia River and Kotah will enable the Engineer to the State to decide whether a proper site for a reservoir can be found, for it is clear that the water must be mainly supplied from the catchment of the Alnia River; if, as I believe probable, no suitable reservoir site can be found, then the whole attention of the State Engineer should be directed to the river project. In consultation with the Medical Officer of the State the question should be pushed to an early determination, and I shall be glad to instruct Mr. Tickell further if he will place his difficulties before me.

(True Copy.)

(Sd.) F. M. ALVARIZ,

Superintendent, Public Works Department Secretariat,
Rajputana and Central India

KOTAH WATER-WORKS.

APPENDIX B.

Gauge Readings of the River Chumbal,
1896.

March

Month and Date.		Gauge A.				Gauge B.				Gauge C.				Gauge D.			
		R. L. of zero=734·2.				R. L. of zero=734·1.				R. L. of zero=743·8.				R. L. of zero=764·4.			
		Reading.		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.
Month.	Date.	9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.		
March, 1896.	7th									0·8		744·6	336				
	8th									0·7		744·5					
	9th									0·7		744·5					
	10th									0·6		744·4					
	11th									0·6		744·4					
	12th									0·5		744·3					
	13th									0·4		744·2					
	14th									0·4		744·2					
	15th									0·4		744·2	119				
	16th									0·4		744·2					
	17th									0·4		744·2					
	18th									0·4		744·2					
	19th									0·4		744·2					
	20th									0·3		744·1	66				
	21st									0·3		744·1					
	22nd									0·2		744·0					
	23rd									0·2		744·0					
	24th									0·2		744·0					
	25th									0·2		744·0					
	26th									0·2		744·0					
	27th									0·2		744·0					
	28th									0·2		744·0					
	29th									0·1		743·9					
	30th									0·1		743·9					
	31st									0·1		743·9	10				

River Chumbal during 1896.

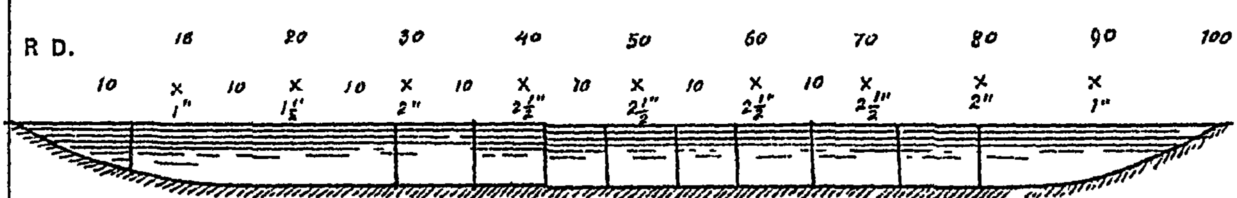
1896.

REMARKS.

Discharge observed by Mr. R. H. Tickell, on March 31, 1896, at the discharge wall and Gauge C.

Gauge reading at "C" on March 31, 1896, = 0·10.

∠ Observed velocity 10' run = 0·5' per second × velocity 0·55 foot per second × V = 0·7.



Discharge = (40 × 0' 2" × 0·5) + (50 × ⅙ × ·55) = 3·33 + 4·9 = 8·2 feet per second as compared with 10 cubic feet per second as calculated for a gauge of 0 10.

Month and Date.		Gauge A.				Gauge B				Gauge C.				Gauge D.			
		R. L. of zero=734·2.				R. L. of zero=734·1.				R. L. of zero=743·8.				R. L. of zero=764·4.			
		Reading.		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.
Month.	Date.	9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.		
April, 1896.	1st									0·2		744·0	Assumed from observed discharge to be 8 cubic feet per second throughout the month.				
	2nd									0·2		744·0					
	3rd									0·2		744·0					
	4th									0·2		744·0					
	5th									0·2		744·0					
	6th									0·1		743·9					
	7th									0·1		743·9					
	8th									0·1		743·9					
	9th									0·1		743·9					
	10th									0·1		743·9					
	11th									0·1		743·9					
	12th									0·1		743·9					
	13th									0·1		743·9					
	14th									0·1		743·9					
	15th									0·1		743·9					
	16th									0·1		743·9					
	17th									0·1		743·9					
	18th									0·1		743·9					
	19th									0·1		743·9					
	20th									0·1		743·9					
	21st									0·1		743·9					
	22nd									0·1		743·9					
	23rd									0·1		743·9					
	24th									0·1		743·9					
	25th									0·1		743·9					
	26th									0·1		743·9					
	27th									0·1		743·9					
	28th									0·1		743·9					
	29th									0·1		743·9					
	30th									0·1		743·9					

River Chumbal during 1896.

1896.

REMARKS.

Gauges and Discharges of the

May

Month and Date.		Gauge A. R. L. of zero=734·2.				Gauge B. R. L. of zero=734·1.				Gauge C. R. L. of zero=743·8.				Gauge D. R. L. of zero=764·4.			
Month.	Date.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
May, 1896.	1st									0·05		743·9	Discharge assumed as 4 feet per second.—, 7				
	2nd									0·05		743·9					
	3rd									0·05		743·9					
	4th									0·05		743·9					
	5th									0·05		743·9					
	6th									0·05		743·9					
	7th									0·05		743·9					
	8th									0·05		743·9					
	9th									0·05		743·9					
	10th									0·02		743·8					
	11th									0·02		743·8					
	12th									0·02		743·8					
	13th									0·02		743·8					
	14th									0·02		743·8					
	15th									0·02		743·8					
	16th									0·02		743·8					
													Discharge assumed, *nil.*				

River Chumbal during 1896.

1896.

Remarks.

June

Month and Date.		Gauge A. R. L. of zero=734·2.				Gauge B. R. L. of zero=734·1.				Gauge C. R. L. of zero=743·8.				Gauge D. R. L. of zero=764·4.			
Month.	Date.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.* 9 A.M.	*Reading.* 6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
												Gauge readings not recorded.	Discharge assumed to be *nil*.				

River Chumbal during 1896.

1896.

REMARKS.

Month and Date.		Gauge A. R. L. of zero=734·2.				Gauge B. R. L. of zero=734·1.				Gauge C. R. L. of zero=743·8.				Gauge D. R. L. of zero=764·4.			
		Reading.				*Reading.*				*Reading.*				*Reading.*			
Month.	Date.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
July 1896	25th	4·6	...	738·8		7·4		741·5		1·0		744·8	540	...		...	
	26th	4·8	...	739·0		7·4		741·5		1·0		744·8	540	1·3		765·7	
	27th	5·0	5·7	739·2		7·9		742·0		1·0		744·8	540	1·2		765·6	
	28th	6·8	7·2	741·0		9·2		743·3		3·0		746·8	Discharge much above 500 feet per second.	4·0		768·4	
	29th	7·4	7·7	741·6		9·4		743·5		3·2		747·0		4·5		768·9	
	30th	7·8	10·9	742·0		12·4		746·5		5·7		749·5		7·5		771·9	
	31st	22·5	29·0	756·7		24·7		758·8		20·2		764·0		23·0		787·4	

River Chumbal during 1896.

1896.

REMARKS.

Month and Date.		Gauge A.				Gauge B.				Gauge C.				Gauge D.			
		R. L. of zero=734·2.				R. L. of zero=734·1.				R. L. of zero=743·8				R. L. of zero=764·4.			
		Reading.		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.	*Reading.*		R. L. of water surface A.M.	Calculated discharge A.M.
Month.	Date.	9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.			9 A.M.	6 P.M.		
Aug., 1896	1st	35·0	28·0	769·2		41·4		775·5		36·0		779·8		36·0		800·4	
	2nd	20·0	17·0	754·2		30·2		764·3		14·0		757·8		14·0		778·4	
	3rd	14·3	14·0	748·5		21·4		755·5		15·5		759·3		18·3		782·7	
	4th	13·5	28·0	747·7		19·9		754·0		13·0		756·8		12·8		777·2	
	5th	37·0	32·0	771·2		38·4		772·5		32·0		775·8		31·0		795·4	
	6th	25·5	20·0	759·7		31·4		765·5		25·0		768·8		30·0		794·4	
	7th	15·5	13·0	749·7		18·4		752·5		12·0		755·8		13·0		777·4	
	8th	12·0	11·8	746·2		12·4		746·5		8·0		751·8		11·0		775·4	
	9th	10·9	12·0	745·1		11·4		745·5		9·0		752·8		11·5		775·9	
	10th	11·3	10·8	745·5		10·4		744·5		5·3		749·1		7·5		771·9	
	11th	9·7	9·0	743·9		10·3		744·4		4·0		747·8		4·3		768·7	
	12th	8·5	12·5	742·7		9·4		743·5		3·5		747·3		3·9		768·3	
	13th	20·0	17·5	754·2		16·3	17·8	750·4		20·5	18·0	764·3		18·0	18·3	782·4	
	14th	14·0	13·5	748·2		14·0	12·8	748·1		15·0	14·5	758·8		14·3	15·0	778·7	
	15th	13·0	34·0	747·2		14·8	29·0	748·9		16·0	31·0	759·8	Discharges much above 500 feet per second.	16·0	28·0	780·4	
	16th	44·0	37·0	778·2		42·0	39·0	776·1		46·0	39·0	789·8		39·0	41·0	803·4	
	17th	22·0	17·5	756·2		25·0	16·5	759·1		22·3	18·0	766·1		23·3	18·0	787·7	
	18th	14·5	13·0	748·7		13·8	12·8	747·9		13·3	12·0	757·1		12·0	9·8	776·4	
	19th	12·0	11·3	746·2		12·0	8·2	746·1		11·0	8·5	754·8		9·3	8·3	773·7	
	20th	10·3	10·0	744·5		15·9		750·0		9·8	9·0	753·6		9·8	9·0	774·2	
	21st	9·5	9·3	743·7		15·4		749·5		9·0	8·8	752·8		9·0	8·8	773·4	
	22nd	9·2	9·0	743·4		15·1		749·2		8·8	8·0	752·6		8·8	8·0	773·2	
	23rd	8·7	8·5	742·9		14·2		748·3		7·8	7·5	751·6		7·5	7·5	771·9	
	24th	8·3	8·0	742·5		13·7		747·8		7·4	7·3	751·2		7·4	7·3	771·8	
	25th	8·0	7·8	742·2		13·4		747·5		7·0	7·0	750·8		7·0	7·0	771·4	
	26th	7·5	7·8	741·7		13·4		747·5		7·0	7·0	750·8		7·0	7·0	771·4	
	27th	8·0	8·8	742·2		12·4		746·5		6·1	7·1	749·9		6·1	7·1	770·5	
	28th	9·8	12·5	744·0		13·4		747·5		8·3	9·8	752·1		8·3	9·8	772·7	
	29th	16·0	15·8	750·2		15·4		749·5		17·0	15·7	760·8		17·0	15·7	781·4	
	30th	15·5	15·3	749·7		14·4		748·5		15·0	15·0	758·8		15·0	15·0	779·4	
	31st	13·5	13·0	747·7		13·9		748·0		13·0	12·0	756·8		13·0	12·5	777·4	

River Chumbal during 1896.

1896.

REMARKS.

Month and Date.		GAUGE A. R. L. of zero=734·2.				GAUGE B. R. L. of zero=734·1.				GAUGE C. R. L. of zero=743·8.				GAUGE D. R. L. of zero=764·4.			
		Reading.				*Reading.*				*Reading.*				*Reading.*			
Month.	Date.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
Sept. 1896.	1st	12·3	11·5	746·5		13·4		747·5		12·0	11·2	755·8	Discharges much above 500 cubic feet per second.	12·0	11·3	776·4	
	2nd	10·0	9·6	744·2		13·4		747·5		10·0	9·2	753·8		10·0	9·2	774·4	
	3rd	9·0	8·5	743·2		12·9		747·0		8·1	7·5	751·9		8·1	7·5	772·5	
	4th	8·0	8·0	742·2		12·6		746·7		7·0	7·0	750·8		7·0	7·0	771·4	
	5th	8·0	7·9	742·2		11·8		745·9		6·8	6·6	750·6		6·8	6·6	771·2	
	6th	7·5	7·5	741·7		12·2		746·3		6·3	6·3	750·1		6·3	6·3	770·7	
	7th	7·3	7·2	741·7		11·9		746·0		6·0	6·0	749·8		6·0	6·0	770·4	
	8th	7·0	7·0	741·2		11·7		745·8		6·0	6·0	749·8		5·8	5·8	770·2	
	9th	6·8	6·8	741·0		11·6		745·7		5·8	5·8	749·6		5·7	5·8	770·1	
	10th	6·8	6·7	741·0		11·4		745·5		5·6	5·5	749·4		5·5	5·4	769·9	
	11th	6·7	6·7	740·9		11·4		745·5		5·2	5·0	749·0		5·1	5·0	769·5	
	12th	6·6	6·6	740·8		11·2		745·3		4·8	4·7	748·6		4·8	4·8	769·2	
	13th	6·5	6·5	740·7		10·2		744·3		4·4	4·3	748·2		4·4	4·3	768·8	
	14th	6·4	6·4	740·6		9·9		744·0		4·1	4·0	747·9		4·1	4·0	768·5	
	15th	6·3	6·3	740·5		9·6		743·7		3·8	3·3	747·6		3·8	3·3	768·2	
	16th	6·3	6·3	740·5		8·9		743·0		2·3	2·3	746·1		2·3	2·3	766·7	
	17th	6·4	6·3	740·6		8·7		742·8		2·3	2·3	746·1		2·3	2·3	766·7	
	18th	6·3	6·3	740·5		8·7		742·8		2·2	2·1	746·0		2·1	2·1	766·5	
	19th	6·2	6·2	740·4		8·9		743·0		2·2	2·2	746·0		2·2	2·2	766·6	
	20th	6·2	6·2	740·4		8·7		742·8		2·2	2·2	746·0		2·2	2·2	766·6	
	21st	6·2	6·1	740·4		8·8		742·9		2·2	2·2	746·0		2·2	2·2	766·6	
	22nd	6·1	6·1	740·3		8·7		742·8		2·2	2·2	746·0		2·2	2·2	766·6	
	23rd	6·1	6·1	740·3		8·7		742·8		2·1	2·1	745·9		2·1	2·1	766·5	
	24th	6·0	6·0	740·2		8·7		742·8		2·1	2·1	745·9		2·1	2·1	766·5	
	45th	6·0	6·0	740·2		8·7		742·8		2·1	2·1	745·9		2·1	2·1	766·5	
	26th	6·0	6·0	740·2		8·7		742·8		2·1	2·1	745·9		2·1	2·1	766·5	
	27th	5·9	6·9	740·1		8·6		742·7		2·1	2·1	745·9		2·1	2·1	766·5	
	28th	5·8	5·9	740·0		8·6		742·7		2·1	2·1	745·9		2·1	2·1	766·5	
	29th	5·8	5·8	740·0		8·6		742·7		2·0	2·0	745·8		2·0	2·0	766·4	
	30th	5·8	5·8	740·0		8·6		742·7		2·0	2·0	745·8		2·0	2·0	766·4	

River Chumbal during 1896.

1896.

REMARKS.

October

Month and Date.		Gauge A. R. L. of zero=734·2.				Gauge B. R. L. of zero=734·1.				Gauge C. R. L. of zero=743·8.				Gauge D. R. L. of zero=764·4.			
		Reading.				Reading.				Reading.				Reading.			
Month.	Date.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
Oct, 1896.	1st	5·7	5·7	739·9		8·5		742·6		2·0	2·0	745·8	Discharges all above 500 cubic feet per second.	1·9	1·9	766·3	
	2nd	5·7	5·7	739·9		8·5		742·6		1·8	1·8	745·6		1·8	1·8	766·2	
	3rd	5·6	5·6	739·8		8·4		742·5		1·8	1·8	745·6		1·8	1·8	766·2	
	4th	5·6	5·5	739·8		8·4		742·5		1·8	1·8	745·6		1·8	1·8	766·2	
	5th	5·5	5·5	739·7		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	6th	5·4	5·4	739·6		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	7th	5·4	5·4	739·6		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	8th	5·3	5·3	739·5		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	9th	5·3	5·3	739·5		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	10th	5·3	5·3	739·5		8·4		742·5		1·7	1·7	745·5		1·7	1·7	766·1	
	11th	5·3	5·3	739·5		8·4		742·5		1·4	1·4	745·2		1·4	1·4	765·8	
	12th	5·2	5·3	739·4		8·4		742·5		1·3	1·3	745·1		1·3	1·3	765·7	
	13th	5·1	5·1	739·3		8·4		742·5		1·3	1·3	745·1		1·3	1·3	765·7	
	14th	5·1	5·1	739·3		8·4		742·5		1·2	1·2	745·0		1·2	1·2	765·6	
	15th	5·1	5·1	739·3		8·4		742·5		1·2	1·2	745·0		1·2	1·2	765·6	
	16th	5·1	5·1	739·3		8·4		742·5		1·2	1·2	745·0		1·2	1·2	765·6	
	17th	5·1	5·1	739·3		8·4		742·5		1·2	1·2	745·0		1·2	1·2	765·6	
	18th	5·1	5·1	739·3		8·3		742·4		1·1	1·1	744·9		1·1	1·1	765·5	
	19th	5·1	5·1	739·3		8·2		742·3		1·1	1·1	744·9		1·1	1·1	765·5	
	20th	5·0	5·0	739·2		8·1		742·2		1·0	1·0	744·8	540	1·0	1·0	765·4	
	21st	5·0	5·0	739·2		8·1		742·2		1·0	1·0	744·8	520	1·0	1·0	765·4	
	22nd	5·0	5·0	739·2		8·1		742·2		1·0	1·0	744·8	500	1·0	1·0	765·4	
	23rd	5·0	5·0	739·2		8·0		742·1		0·9	0·9	744·7	480	0·9	0·9	765·3	
	24th	5·0	5·0	739·2		8·0		742·1		0·9	0·9	744·7	460	0·9	0·9	765·3	
	25th	4·9	4·9	739·1		7·9		742·0		0·8	0·8	744·6	440	0·8	0·8	765·2	
	26th	4·9	4·9	739·1		7·4		741·5		0·8	0·8	744·6	430	0·8	0·8	765·2	
	27th	4·8	4·8	739·0		6·9		741·0		0·8	0·8	744·6	420	0·8	0·8	765·2	
	28th	4·8	4·8	739·0		6·4		740·5		0·8	0·8	744·6	410	0·8	0·8	765·2	
	29th	4·7	4·7	738·9		5·9		740·0		0·7	0·7	744·5	400	0·7	0·7	765·1	
	30th	4·7	4·7	738·9		5·7		739·8		0·7	0·7	744·5	390	0·7	0·7	765·1	
	31st	4·7	4·7	738·9		5·6		739·7		0·7	0·7	744·5	380	0·7	0·7	765·1	

River Chumbal during 1896.

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Remarks.

Month and Date: Month	Month and Date: Date	Gauge A. R. L. of zero=734·2. Reading 9 A.M.	Gauge A. Reading 6 P.M.	Gauge A. R. L. of water surface A.M.	Gauge A. Calculated discharge A.M.	Gauge B. R. L. of zero=734·1. Reading 9 A.M.	Gauge B. Reading 6 P.M.	Gauge B. R. L. of water surface A.M.	Gauge B. Calculated discharge A.M.	Gauge C. R. L. of zero=743·8. Reading 9 A.M.	Gauge C. Reading 6 P.M.	Gauge C. R. L. of water surface A.M.	Gauge C. Calculated discharge A.M.	Gauge D. R. L. of zero=764·4. Reading 9 A.M.	Gauge D. Reading 6 P.M.	Gauge D. R. L. of water surface A.M.	Gauge D. Calculated discharge A.M.
Nov., 1896.	1st	4·6	4·6	738·8		5·5		739·6		0·7	0·7	744·5	370	0·7	0·7	765·1	
	2nd	4·6	4·6	738·8		5·5		739·6		0·7	0·7	744·5	360	0·7	0·7	765·1	
	3rd	4·6	4·6	738·8		5·5		739·6		0·7	0·7	744·5	350	0·7	0·7	765·1	
	4th	4·6	4·6	738·8		5·5		739·6		0·6	0·6	744·4	340	0·6	0·6	765·0	
	5th	4·6	4·6	738·8		5·5		739·6		0·6	0·6	744·4	340	0·6	0·6	765·0	
	6th	4·6	4·6	738·8		5·5		739·6		0·6	0·6	744·4	337	0·6	0·6	765·0	
	7th	4·6	4·6	738·8		5·5		739·6		0·6	0·6	744·4	337	0·6	0·6	765·0	
	8th	4·6	4·6	738·8		5·4		739·5		0·6	0·6	744·4	337	0·6	0·6	765·0	
	9th	4·6	4·6	738·8		5·4		739·5		0·5	0·5	744·3	317	0·5	0·5	764·9	
	10th	4·6	4·6	738·8		5·4		739·5		0·5	0·5	744·3	317	0·5	0·5	764·9	
	11th	4·5	4·5	738·7		5·2		739·3		0·5	0·5	744·3	317	0·5	0·5	764·9	
	12th	4·5	4·5	738·7		5·2		739·3		0·5	0·5	744·3	317	0·5	0·5	764·9	
	13th	4·5	4·5	738·7		5·2		739·3		0·4	0·4	744·2	310	0·4	0·4	764·8	
	14th	4·5	4·5	738·7		5·2		739·3		0·4	0·4	744·2	310	0·4	0·4	764·8	
	15th	4·5	4·5	738·7		5·2		739·3		0·4	0·4	744·2	310	0·4	0·4	764·8	
	16th	4·5	4·5	738·7		5·2		739·3		0·3	0·3	744·1	304	0·3	0·3	764·7	
	17th	4·5	4·5	738·7		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	18th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	19th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	20th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	21st	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	22nd	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	23rd	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	24th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	25th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	26th	4·4	4·4	738·6		5·1		739·2		0·3	0·3	744·1	304	0·3	0·3	764·7	
	27th	4·4	4·4	738·6		5·0		739·1		0·3	0·3	744·1	304	0·3	0·3	764·7	
	28th	4·3	4·3	738·5		5·0		739·1		0·3	0·3	744·1	304	0·2	0·2	764·6	
	29th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	300	0·2	0·2	764·6	
	30th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	299				

River Chumbal during 1896.

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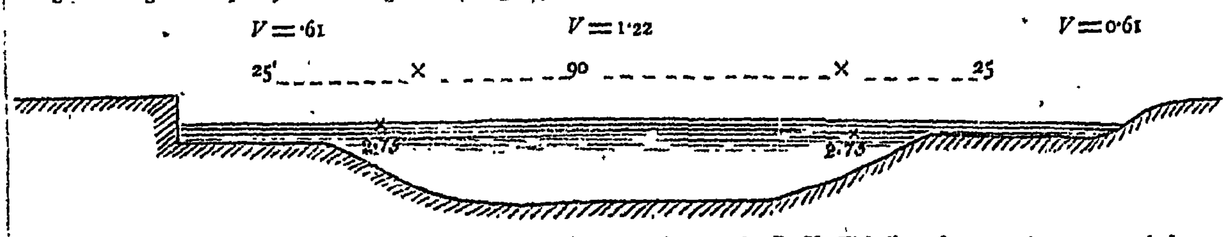
REMARKS.

Rough discharge taken 9-11-96 at discharge wall (Gauge C) wall broken.



Gauge reading 0·5 Discharge taken by Mr. R. H. Tickell, 20 feet run, time 14 seconds for centre portion 90 feet and half this velocity at each end.

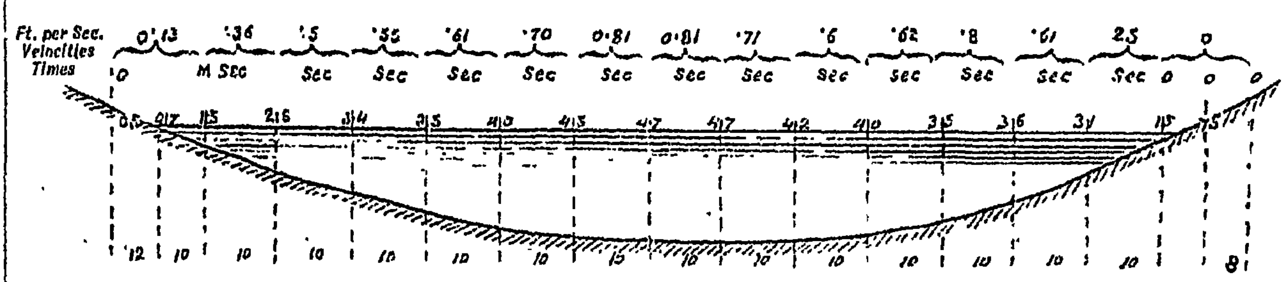
$$D = (50 \times 0{\cdot}5 \times {\cdot}61) + (90 \times 2{\cdot}75 \times 1{\cdot}22)$$

$$= 15{\cdot}5 + 310{\cdot}95 = 317 \text{ c. ft. per section.}$$

Discharge taken 500 feet above Gauge C in pool on 20-11-96 by Overseer, Abdul Latif.

D. = 2·86 + 7·98 + 15 + 18·7 + 22·57 + 29·4 + 37·26 + 38·07 + 31·24 + 24·6 + 25·94 + 26·4 + 18·3 + 5·7 + 0 = 304·02

Arrears = 22 × 21 × 30 × 34 × 37 × 42 × 46 × 47 × 44 × 41 × 37 × 33 × 30 × 23 × ×



D. = (22 + 0·13) + (21 + ·38) + (30 + ·5) + (34 × 55) + (37 + 61) + (42 + ·35) + (46 + ·81) + (47 + 81) + (44 + ·71) + (41 + ·6) + (37 × 62) + (33 + ·8) + (30 + ·61) + (23 + ·25) = 304·02 for a gauge reading at C of 0'·3

Month and Date.		Gauge A. R. L. of zero=734·2.				Gauge B. R. L. of zero=734·1.				Gauge C. R. L. of zero=743·8.				Gauge D. R. L. of zero=764·4.			
		Reading.				Reading.				Reading.				Reading.			
Month.	Date.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.	9 A.M.	6 P.M.	R. L. of water surface A.M.	Calculated discharge A.M.
Dec., 1896.	1st	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	298	0·2	0·2	764·6	
	2nd	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	297	0·2	0·2	764·6	
	3rd	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	296	0·2	0·2	764·6	
	4th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	295	0·2	0·2	764·6	
	5th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	294	0·2	0·2	764·6	
	6th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	293	0·2	0·2	764·6	
	7th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	292	0·2	0·2	764·6	
	8th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	291	0·2	0·2	764·6	
	9th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	288	0·2	0·2	764·6	
	10th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	285	0·2	0·2	764·6	
	11th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	282	0·2	0·2	764·6	
	12th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	279	0·2	0·2	764·6	
	13th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	276	0·2	0·2	764·6	
	14th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	274	0·2	0·2	764·6	
	15th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	272	0·2	0·2	764·6	
	16th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	270	0·2	0·2	764·6	
	17th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	267	0·2	0·2	764·6	
	18th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	264	0·2	0·2	764·6	
	19th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	261	0·2	0·2	764·6	
	20th	4·3	4·3	738·5		5·0		739·1		0·2	0·2	744·0	258	0·2	0·2	764·6	
	21st	4·2	4·2	738·4		4·9		739·0		0·2	0·2	744·0	255	0·2	0·2	764·6	
	22nd	4·2	4·2	738·4		4·9		739·0		0·2	0·2	744·0	252	0·2	0·2	764·6	
	23rd	4·2	4·2	738·4		4·9		739·0		0·2	0·2	744·0	249	0·2	0·2	764·6	
	24th	4·2	4·2	738·4		4·9		739·0		0·2	0·2	744·0	246	0·2	0·2	764·6	
	25th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	244	0·2	0·2	764·6	
	26th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	242	0·2	0·2	764·6	
	27th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	240	0·2	0·2	764·6	
	28th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	239	0·2	0·2	764·6	
	29th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	236	0·2	0·2	764·6	
	30th	4·1	4·1	738·3		4·8		738·9		0·2	0·2	744·0	235	0·2	0·2	764·6	
	31st	4·0	4·0	738·2		4·8		738·9		0·2	0·2	744·0	231	0·2	0·2	764·6	

1896.

REMARKS.
On the 8th December the discharge given at Gauge C was observed by Overseer Abdul Latif.
On the 31st December the discharge given at Gauge C was observed.

R. [illegible]. TICKELL,
State Engineer, Kotah and Jhallawar.

KOTAH WATER-WORKS REPORT.

APPENDIX C.

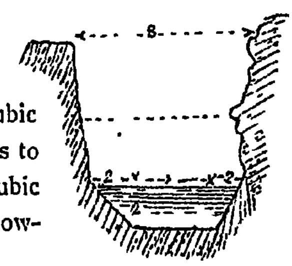
CALCULATIONS

(1) *Abstract No I.—River-bed Channels*

Slope—2 per 1,000.

Bed—4 feet.

Depth—2 feet Side slopes—1 to 1.



Discharge = 35 cubic feet per second

For a depth of 4 feet the discharge will be 120 cubic feet per second, which will be enough for two turbines to work together for 19 hours a day. The discharge of 35 cubic feet per second for a 2-foot depth will be ample for the low-level turbine to work 12 hours a day.

Channel No. 1 may be made as above, and channels Nos. 2 and 3 of the same section, but with a level bed.

(2) *Abstract No II.—Bund in Chumbal River.*

The water bunded up between the level 669 and 665 measured on the longitudinal and cross sections of the river comes to 27·6 million cubic feet.

Discharge of 2-foot Scour-valves at R. L. 659 in Bund.

When the bund is full head to centre of valves = 9 feet.

Velocity of discharge $\sqrt{2gh} = 24{\cdot}1$.

Discharge in cubic feet per second = $8\times3,\ 14\times24,\ 1\times60\ 5$.

Similarly discharges for heads of—

8 feet ...	... D=	2·5 × 22·7 = 56 7	c. ft. per sec.
7 " ...	... D=	2·5 × 21·2 = 53	" "
6 " ...	... D=	2·5 × 19·7 = 49·2	" "
5 " ...	... D=	2·5 × 17·9 = 44·7	" "
4 " ...	... D=	2·5 × 16 = 40	" "
3 " ...	... D=	2·5 × 13·9 = 34·7	" "
2 " ...	... D=	2 5 × 11·4 = 28·5	" "
1 " ...	... D=	2·5 × 8·0 = 20	" "

Or average discharges for heads varying from—

9 feet to 7 feet	may be taken as	57	c. ft. per sec.
7 " " 5 "	" "	49	" "
5 " " 3 "	" "	40	" "
3 " " 1 "	" "	27	" "

The water stored in Pool No. 2 between the contours—

769	and	767	is	5,260,000 c. ft.
767	"	765	is	4,840,000 "
765	"	763	"	4,480,000 "
763	"	761	"	4,120,000 "
761	"	759	"	3,500,000 "

Hence the times taken to empty Pool No. 2 by one stop-valve of 2 feet at R L. 759 down to—

R. L. 767	would be	1·07 days.
" 765	"	1·00 "
" 763	"	0·91 "
" 761	"	1·50 "
" 760	"	1·02 "
Total		5·5 days.

So three stop-valves would empty Pool No. 2 in less than two days.

N.B.—Pool No. 2 should have a regulator at Rapid No 2 so as to be emptied independent of Pools Nos. 3 and 4.

(4) *Outlet Gates of Aqueduct.*

With 4 feet of water these should be sufficient to discharge the full supply of water discharged by the aqueduct, *i.e.* say, 150 cubic feet per second. The velocity of water in the aqueduct (see below) is 3·93 cubic feet per second. Assuming at 3·25 feet per second will be the velocity at the outlet, then four gates 3 feet wide by 4 feet deep will be sufficient.

(5) *Abstract No. III.—Aqueduct to Turbine Wells.*

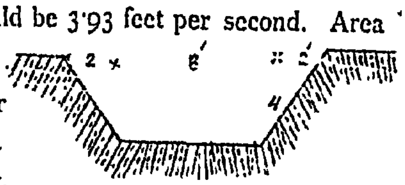
The R. L. of the bed of this at the bund is 765.

Depth taken—4 feet

R L of bed at the turbine wells =763, so there is a fall of 2 feet in its length—2,500 feet—*i.e.*, it has a slope of 0·8 per 1,000.

N = 0·017.

For a bed, width of 8 feet, the mean velocity would be 3·93 feet per second. Area of a channel as per sketch would be 40 square feet.



So discharge would be 157, which is sufficient for two turbines working together (*vide* para. 6). One foot extra in height may be allowed to prevent overflow.

(6) *Abstract No. IV.—Turbines, Pumps and Rising Main.*

The calculations for these will be left to the makers. For the sake of the estimate, however, the diameter of the rising main may be taken in inches to be

$$\sqrt{\frac{\text{gals. per minute}}{2\,v.}}$$

Take $v = 3$ feet per second.

$$D'' = \sqrt{\frac{833}{6}}$$

$$= 11·9 \text{ or, say, } 12 \text{ inches.}$$

Thickness of metal—$\frac{3}{8}$ inch.

Weight per 9-foot length—9cwt. 3qrs. 5lbs.

(Hurst, p. 175.)

(7) *Pump Horse-Power.*

The pump H.-P. required is $= \frac{\text{gals. per min.} \times \text{wt. of 1 gal.} \times \text{H.}}{33{,}000}$.

H=difference between level of top of high-level tank and L.-W.-L. of Chumbal +frictional head

$$=\text{say, } 1{,}028-736+20$$
$$=312$$
$$\therefore \text{P. H.-P.} = \frac{833 \times 10 \times 312}{33{,}000}$$
$$=78$$

(8) *Turbine Horse-Power.*

The discharge required in the river for a working fall of 20 feet would be—

$$2\,(\text{P. H.-P.}) = \frac{\text{D} \times 20}{529}$$
$$\text{D} = \frac{2\,(\text{P. H.-P.})529}{20}$$
$$=4{,}136 \text{ c. ft. per minute.}$$
$$=69 \text{ c. ft. per second.}$$

For a working fall of 15 feet—

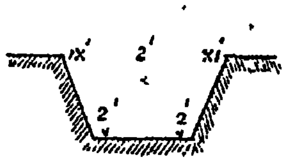
$$\text{D} = \frac{2 \times 78 \times 529}{15}$$
$$=5{,}502 \text{ c. ft. per minute.}$$
$$=92 \text{ c. ft. per second.}$$

The above discharges are on the assumption that the turbines will have an efficiency of 0·5; but as most turbines have an efficiency of from 0·6 to 0·8 it will be quite safe to assume that 65 cubic feet per second will be required for the low-level turbine and 86 cubic feet per second for the high-level turbine.

(9) *Abstract No. 6.—High-Level Tank and Masonry Duct to Collecting Tank.*

The masonry duct must be made of sufficient capacity to discharge all the water that both pumps are capable of delivering. Each pump can deliver 600,000 gallons in 12 hours, *i.e.*, 833 gallons per minute—say, 14 gallons per second or 2·24 cubic feet per second.

The discharging capacity of the masonry duct should therefore be not less than 4·48—slope 1 per 1,000. A masonry duct of the annexed shape will be ample, its discharging capacity being 1·08 cubic foot per second.



(10) *Abstract No. 7.—Collecting Tank.*

The Masonry Bund.—The pressures on this are shewn in a pressure diagram accompanying Plan No. X.

The weight of the masonry is taken as 125lbs. per cubic foot.

(11) *Capacity of Tank.*

600,000 gallons a day=96,000 cubic feet a day.
=2,880,000 cubic feet a month.
4 months' supply=11,520,000 cubic feet.

This would be given by a tank 1,000×1,000×11·5. From the plan it will be seen that this capacity is allowed.

(12) *Waste Weir.*

Drainage area of tank=5 sq. mi.
=139·39 mill. c. ft.
Area of tank at R. L. 1,015=1·84 mill. c. ft.

Assume a rainfall of 4 inches per hour. Weir 2,000 feet long at R. L. 1,015.

Divide the hour into periods of 5 minutes and consider each 5 minutes' discharge.

1st Hour, 1st 5 Minutes.

Rainfall $= 139{\cdot}4 \times \frac{1}{36} = 3{\cdot}87$ mill. c. ft.

Rise in tank (theoretical) $\frac{3{\cdot}87}{1{\cdot}84} = 2{\cdot}1$ ft. Assume the weir discharges for 5 minutes with an average height of 0·5 foot.

Discharge $= 39{\cdot}24 \times \frac{5 \times 2{,}000 \times 12}{625}$ (Hennell's Hydraulic Tables, p. 15).

Discharge $= 39{\cdot}2 \times 19{,}200$

$= 0{\cdot}75$

Water in tank at end of 5 min.	$= 3{\cdot}87 - 0{\cdot}75.$
	$= 3{\cdot}12$ mill. c. ft.
Actual rise at weir at end of 1st 5 min.	$= \frac{3{\cdot}12}{1{\cdot}84} = 1{\cdot}7$ foot.

1st Hour, 2nd 5 Minutes.

Water in tank at end of 2nd 5 min.	$= 3{\cdot}12 + 3{\cdot}87.$
	$= 6{\cdot}99$ mill. c. ft.
Discharge at weir with 1·7 ft. of water in 5 min.	
	$= 250 \times 19{,}200.$
	$= 4{\cdot}8$ mill. c. ft.
Water left in tank at end of 2nd 5 min.	$= 6{\cdot}99 - 4{\cdot}8 = 219$ mill. c. ft.
Height over weir at end of 2nd 5 min.	$= \frac{3{\cdot}12}{2{\cdot}91} = 1{\cdot}4$ ft.

The rise therefore at the end of the second 5 minutes is less than at the end of the first 5 minutes, and therefore the weir is sufficient for a discharge of 4 inches per hour.

(13) *Abstract No. 8.—C.-I. Main from Collecting Tank to Filter-beds.*

Level of pipe at collecting-tank is 995.

At filter-beds the H. W.-L. is 933.

Fall about 5 per 1,000 for the H. M. G.

To discharge 833 gallons per minute in 11-inch C.-I. main will be required.

(14) *Abstract No. 11.—Pipe-distribution (vide* Plan No. 14).

R. H. TICKELL,

State Engineer, Kotah and Jhallawar.

11th January, 1897.

KOTAH WATER-WORKS PROJECT.

APPENDIX D.

List of Plans accompanying Report.

I.—Index Plan Scale 1" = 1 mile.

II.—General Plan contoured 6" = 1 mile.

III.—Longitudinal Section of Chumbal River from Kerer Rapids upwards.

IV.—Cross Sections of Chumbal River.

V.—Plan of Bund, Aqueduct and Turbine Wells contoured.

VI.—Design for Chumbal Bund.

VII.—Design for Turbine Wells.

VIII.—Design for Engine-Driver's house and Workmen's lines.

IX.—Design for High-level Tank.

X.—Design for Collecting Tank.

XI.—Design for Filter-beds.

XII.—Design for Service Reservoir.

XIII.—Plan of Pipe-distribution in and around Kotah.

XIV.—Theoretical discharge, Diagram of C.-I. Pipes

XV.—Index Plan of Hydrants and Special Pipes.

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State Engineer.

Dated 11*th January*, 1897.

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